

## DETECTION OF URBAN PLACES IN OHIO FROM LANDSAT IMAGERY<sup>1</sup>

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**Abstract.** False color Landsat imagery can aid in urban detection with certain limitations. A population threshold of 10,000 appears to be a reliable level for detection in Ohio. At this level, 89% of Ohio urban places were detected. Below this threshold, chances are one in two of detecting an urban place. Accuracy of detection varied with urban size and seasonality of imagery. In general, as city size increased accuracy likewise increased. Area of the city and Central Business District were important factors in detection. Late winter scenes were best for detection while late summer scenes were least favorable.

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The use of Landsat imagery in land use studies and map production is becoming a common operation. Recently, the states of Kansas, Nebraska, and Iowa completed and published land use maps using a combination of data sources including Landsat imagery (Anderson 1976, Nebraska Remote Sensing Center 1973, and Williams and Barker 1973). Land use categories, with some exceptions, followed those recommended by the U.S. Geological Survey Bulletin #671 including the category for urban places (Anderson *et al* 1972). In all cases, it was stated that manually interpreted Landsat imagery aided in locating and mapping urban places. (Urban places for this study are defined as agglomerations of at least 5,000 population.) The resolution capabilities of Landsat imagery create problems involved in detecting urban places in the landscape, such as identifying particular cities and towns. The key term in this study is *detection* rather than *identification*. Detection does not imply *a priori* knowledge of site location. Detection implies finding or recognizing the existence of an urban site while identification implies a degree of familiarity with place location as an input of knowledge into the interpretation process.

Questions addressed in this study are: How much aid is Landsat in urban detection? What is the lowest population threshold necessary for detection? What are identifying characteristics on Landsat imagery of urban places?

A search of available literature reveals that the urban scene has come under the scrutiny of the eye of remote sensors in aircraft at various altitudes and also from spacecraft. The majority of studies using suborbital photography are concerned with topics other than urban detection, since at lower altitudes (hence higher resolution capabilities), rather detailed investigations of transport systems, urban development patterns, and urban blight can be carried out. At orbital altitudes, many details of the urban scene blend into the landscape and thus are not easily distinguished from the surrounding countryside.

To date, relatively few studies of urban detection from space have been undertaken, largely because an emphasis has been placed on land use/cover studies. Ogrosky (1975) used high altitude aircraft photography of 18 sites in the Puget Sound area as a simulation for Skylab imagery. Test sites were limited to urban places of 10,000 or more persons. Altman (1972) supposed that in terms of urban detection "at 500 miles (altitude) there will be a threshold

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size on the order of 500 or more people." Using supportive material from Wellar (1969), Altman further concluded that:

"At 500 miles altitude it is unlikely that any more than the gross land area of the urban place and large arterial roads will be discernible. Central business districts may be interpretable from indications of density of development or the focus of major roads, but except for features of large-scale land use or in rural surroundings such as regional shopping centers, military installations or airports . . . the urban area will just appear as a different gross feature in the general agricultural landscape. The Gemini photographs in Wellar (1969) provide support for these contentions" (Altman 1972, p. 6).

#### METHODS

Using census figures from 1970, all urban

places within Ohio were placed into a 4-tier classification:

- 1) Cities from 5,000 to 9,999
- 2) Cities from 10,000 to 19,999
- 3) Cities from 20,000 to 49,999
- 4) Cities with greater than 50,000 population.

This classification was derived due to the hypothesis that given the resolution capabilities of Landsat, cities with less than 5,000 population could not be detected while those in excess of that figure should cover areas large enough to appear as urban agglomerations. (Essentially, an area of 20 acres in size with a minimum dimension on one side of 800 ft can be detected on Landsat imagery from Landsat 1 and 2 (Draeger *et al.*, p. 120.) Beyond those two points of consideration, the classification was one merely of convenience.

Using a current road map of the state, all cities over 5,000 population were plotted on a frosted mylar sheet with symbols appropriately assigned to each category of urban size previously described (figure 1). This part of the project was carried out by a person who was not a photo interpreter. The resulting map was not consulted until all work on Landsat imagery had been completed in order to elimi-

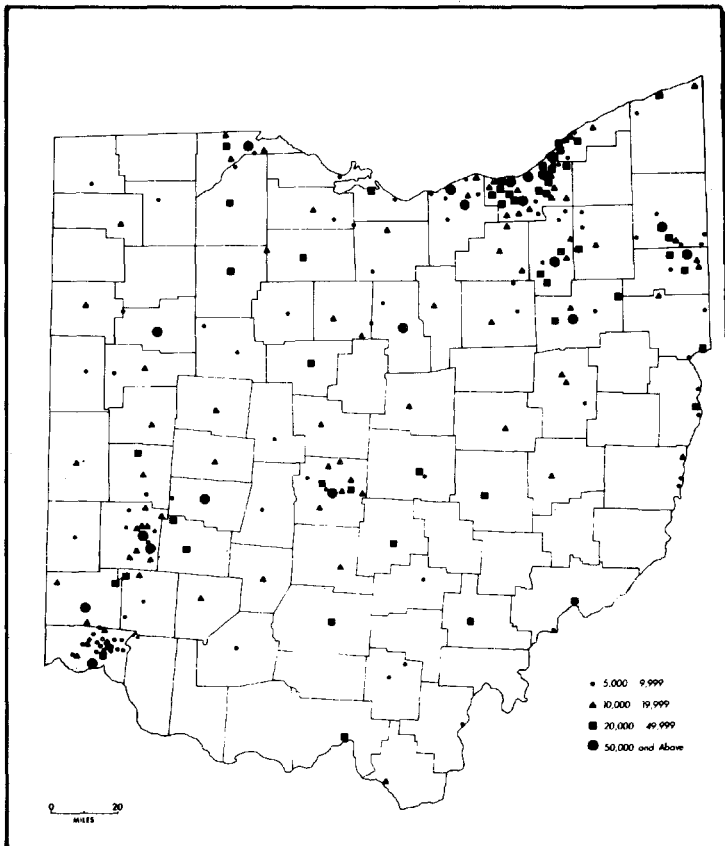


FIGURE 1. Urban places over 5,000 population—Ohio 1970.

nate a degree of bias entering the study from foreknowledge of place location. It is recognized, however, that a degree of familiarity with the state is inevitable in aiding interpretation because, for example, most people know the locations of Toledo, Cleveland, and Cincinnati. But, as one descends the urban hierarchy, familiarity with place location becomes a greater factor in identifying particular urban sites. Since the interpreter did not have a great deal of previous background knowledge of place location in the state, this aspect as an input in detection was negligible.

False color photo transparent positives at a scale of 1:1,000,000 (FCC) covering eight dates from March to September 1973 were manually interpreted. In the interpretation phase of the project, individual Landsat images were overlaid with clear mylar and urban sites marked as they were detected with the naked eye. Subsequently, the same scenes were placed on a Zoom Transfer Scope and magnified at various levels in an attempt to pick out additional sites not detected in the first exercise. Figure 2 is a composite of these 2 operations.

Following the interpretation phase of the project, the findings were tabulated according to city size (table 1). A master sheet was compiled showing all cities over 5,000 popula-

tion with boundaries of the eight Landsat scenes overlain. In this fashion, the advantages of seasonality of imagery and naked eye *vs.* magnified interpretation could be checked. The number of cities detected in each category by scene was recorded along with percent correctly detected *vis-à-vis* the number possible for detection.

## RESULTS

Considering individual Landsat scenes, success in detection of cities in Category 1 (5,000–9,999) ranged from total failure to total success with a composite average of 22% success in detection—not an encouraging finding. As city size increased, success in detection also increased with rates of 50% for Category 2 (10,000–10,999), 54% for Category 3 (20,000–49,999), and 89% for Category 4 (50,000+). These results were not unexpected, assuming that as population increases city area also increases, hence, the greater the likelihood for detection. Yet, the rates of success were not high until the 50,000+ range was reached.

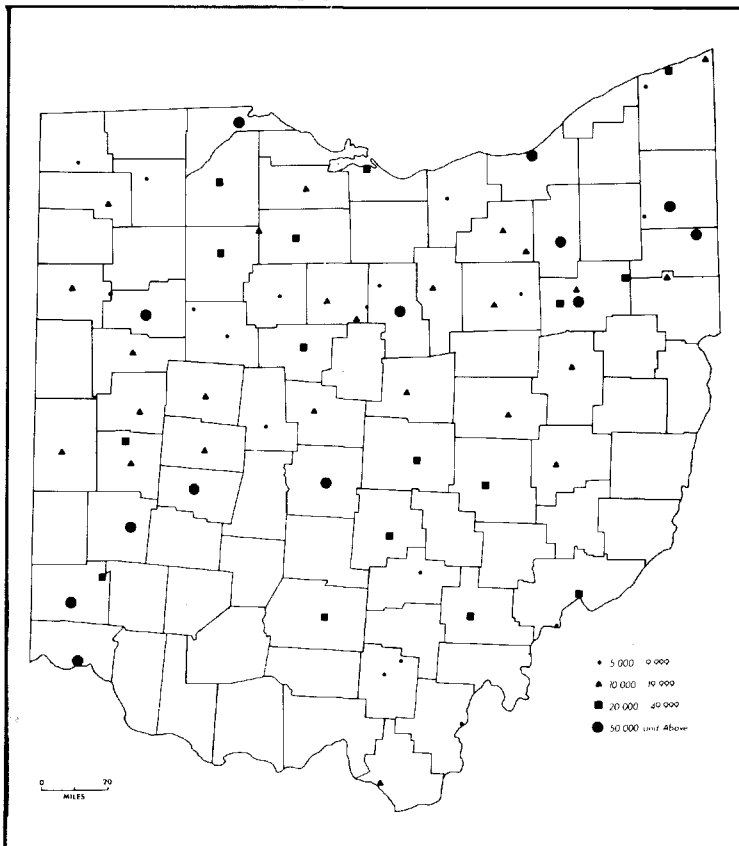


FIGURE 2. Urban places over 5,000 population—detected from Landsat.

TABLE 1  
*Detection of Ohio cities 5,000 to 50,000+ using Landsat FCC imagery.*

Image Date	No. of 5,000-9,999	No. Detected	% Correct	No. of 10,000-19,999	No. Detected	% Correct	No. of 20,000-49,999	No. Detected	% Correct	No. of 50,000+	No. Detected	% Correct
3/ 8/73	4	1	25	9	8	88	4	4	100	1	1	100
3/ 8/73	5	5	100	1	1	100	2	1	50	0	—	—
4/13/73	10	2	20	7	6	85	4	4	100	2	2	100
4/14/73	15	7	46	20	10	50	6	4	67	4	4	100
4/14/73	28	2	7	19	1	5	5	2	40	4	3	75
6/18/73	1	1	100	0	—	—	0	—	—	0	—	—
9/ 3/73	20	2	10	26	6	23	21	4	19	7	4	57
9/ 3/73	9	0	0	4	0	0	4	0	0	1	1	100
	92	20	22	86	32	37	46	19	41	19	15	89

Overall a success rate of 54% was achieved (table 1).

As soon as interpretation commenced, it became evident that the metropolitan areas of Toledo, Columbus, Cincinnati, and Cleveland would present a special problem. Because of the sprawling nature of urbanization in these places, it would be difficult, if not impossible, to pick out individual municipalities within the urban agglomerations. It was well-known that each city had its suburbs; however, the core city and its suburbs coalesce to form one large "metroplex". Success in detecting individual cities here could be considered to be approaching zero, thus the data were re-evaluated with the metroplexes of Toledo, Cleveland, Akron, Dayton, Columbus, Cincinnati, and Youngstown—Warren delimited and all smaller cities in their orb reckoned as part of the complex and non-detectable. When this re-evaluation was done, success increased commensurately.

A total of 243 urban places over 5,000 population were located on a map using census data and a current map of Ohio. On this basis, interpretation commenced to ascertain how many of these 243 places could be detected on Landsat imagery. Eliminating the metroplexes and associated urban places from consideration, this number was reduced to 99. After interpreting the imagery with the naked eye, a Zoom Transfer Scope was used to go over all the imagery. As a result of magnification, an additional

45 urban places were detected, 20 having less than 5,000 population.

With elimination of smaller cities in the "shadow" of the largest urban centers from consideration, success in detection for Category 1 increased to 47%, while accuracy in the top 3 categories became nearly perfect with percentages of 86, 100, and 100, respectively, for categories 2, 3, and 4. Improvement in detection came about in large part because of the isolated nature of the urban places from their rural surroundings. Out in the open landscape, urban places could more easily be seen. Still in the lowest category, a 50% success rate was not achieved. The question of what made the smaller cities more difficult to find warranted a look at seasonality of the imagery. To determine if one season would be better for detection than another, various images were seasonally grouped to see if this made a difference.

Images used by month were 2 in March, 3 in April, 1 in June, and 2 in September. Accordingly, 2 were taken in winter (March 8th scenes), 4 in spring (two April 14th and two June 8th images), and 2 in summer (two September 3rd scenes), with autumn not represented. Four scenes were taken during the growing season when vegetation is active and woody species are leafed out—2 in June and 2 in September. Atmospheric conditions such as haze may affect interpretation reliability, but using color positives with manual interpretation, atmospheric affects could not be evaluated in the final results.

On the April 14th images, some towns as small as 300 population were detected, owing largely to vegetation in towns contrasting with surrounding non-vegetated farmlands. Location on a highway or railroad that "stood out" as a line on the landscape was an additional aid in detecting small urban places, somewhat bearing out the findings of Altman (1972) that road networks are useful in detecting urban places, especially at road intersections. It should be noted that road networks throughout the state could be detected only sporadically and then only under favored conditions of high contrast with adjacent fields. Towns of less than 5,000 population detected were Lordstown (300), Rio Grande (333), Cairo (566), Hamler (588), Arcadia (610), Geneva-on-the-Lake (631), North Perry (658), Perry (885), Waynesville (1,298), Madison (1,347), Holgate (1,374), Deshler (1,824), Utica (1,854), Columbus Grove (2,104), Glouster (2,255), McConnellsville (2,257), Chardon (3,154), Ottawa (3,245), Waverly (3,830, and Nelsonville (4,834).

In detecting towns of less than 5,000 population, several things are worth noting. Even though southeast Ohio has many small towns, very few were detected largely due to extensive forest cover and small areas of urban places. Conversely, in northwest Ohio, lack of forest cover and presence of an agricultural landscape is a definite aid in detection. As mentioned earlier, late winter imagery favored urban detection. Locating a place as small as Lordstown (300) was due in large part to the location of the sprawling General Motors Vega assembly plant there.

Of all the imagery, late winter and early spring scenes proved to be most useful for urban detection for a number of reasons. The rural landscape, especially cropped areas, has not been planted and those areas in crops, like winter wheat and alfalfa, are still dormant; hence, degree of reflectivity is low. The urban places, on the other hand, with well-maintained lawns, cemeteries, and golf courses green up earlier and thus stand out for detection. The main identifying feature for urban places at this time of year is a city center, which

appears like a blue haze blending toward pink in the residential areas. Late winter images for northwest Ohio were especially good for urban detection. In the forested southeast part of the state, the predominant winter landscape color in FCC is gray-green, and cities stand out well against this background if they are sufficiently large. There are, however, few cities over 5,000 population in this part of the state.

Overall, images from June and September were not good, with September being especially poor for urban detection. As the growing season progresses, the majority of the landscape in FCC becomes pink/red and cities, notably those in Categories 1 and 2, blend into the landscape and are "lost" to view due to lushness of vegetation in both urban and rural settings and also to lack of area for smaller cities.

Area of an urban place is a definite aid in detection because it relates to size of the Central Business District (CBD) with its large expanses of buildings, cement and blacktop covering exhibiting a bluish hue in contrast to the surrounding vegetated residential and rural areas that are pink or red. As the growing season progresses and both urban and rural areas become red on the imagery, area in CBD is critical to detection because the larger the CBD, the more likely the city is to be detected. In late summer in Ohio, this threshold is at the 50,000 population level. On the September imagery, no cities below 50,000 population away from metroplexes were detectable, however, on other dates the threshold was much lower.

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